

Balloon borne soundings for the validation of upper tropospheric humidity and temperature

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1. Objectives

The continuing objective of this project is to provide in situ validation measurements of relative humidity and temperature in the middle and upper troposphere for AIRS using cryogenic frost-point hygrometers at various locations and climatic conditions.

2. Accomplishments

The soundings launched for AIRS validation purposes during the report period are summarized in table 1.

An overview of the soundings obtained up to present is given in table 1.

Location	Instruments	# soundings
San Cristóbal, Galapagos	FP/O3/PTU	6
San Cristóbal, Galapagos	PTU	65
San Cristóbal, Galapagos*	O3/PTU	8
Hilo, HI	FP/O3/SW/PTU	2
ARM/CART SGP, Oklahoma	CFH/SW/O3	12 **

Table 1. Dedicated AIRS validation soundings up to present. The instruments used are: FP = NOAA/CMDL frost-point hygrometer, CFH = University of Colorado Cryogenic Frost point Hygrometer, O3 = ECC ozone sonde, PTU = Vaisala RS80-H radiosonde, since Feb 2004 also Vaisala RS90.

*) The ozone soundings at San Cristóbal are dedicated SHADOZ soundings, which are matched with AIRS overpasses. **) These soundings are part of the AWEX campaign.

Comparison between NOAA frost point hygrometer and Vaisala RS90

A validation campaign at San Cristóbal, Galapagos took place in July 2003 with three soundings. Two of these were launched at night; one was launched during the daytime. All three soundings carried Vaisala RS90 radiosondes, however, only two produced data. Three frost point hygrometer soundings at Sodankylä Finland also carried RS90 radiosondes which allow a first evaluation of the RS90 humidity sensor. The RS90 data used here have been corrected for time lag of the sensor. The comparisons between these two instruments are shown in figure 1. At Sodankylä the comparison shows a dry bias for the RS90 sensor of 10-15% throughout the entire troposphere. At San Cristóbal, Galapagos, the dry bias in lower and middle troposphere is around 5-10% and increases in the upper troposphere to 25%. The statistics at this point is not sufficient to quantify this dry bias as function of temperature, pressure and age of sonde. The increasing difference between RS90 and NOAA frost point hygrometer above 12 km is most likely due to an insufficient time lag correction, which was applied here. This region is most difficult for the time lag, since Vaisala measurements of time lag end at -60C and have the strongest temperature dependence in this temperature range.

Beginning in February of 2004, the station at San Cristóbal, Galapagos started using RS90 radiosondes in addition to RS80 radiosondes. These sondes are launched alternately and timed with AIRS overpasses. This launch scheme will provide some further insight in the differences between these two radiosonde models.

The University of Colorado Cryogenic Frost point Hygrometer (CU-CFH)

The number of frost point hygrometer soundings launched during the report period fell behind the projected number due to difficulties in instrument supply and performance problems of the NOAA/CMDL frost point hygrometer in the upper troposphere. To overcome these issues, an improved version of this instrument was developed and built at the Instrument Development Facility of CIREs at the University of Colorado. This instrument, called the University of Colorado Cryogenic Frost point Hygrometer (CU-CFH), has been used during the AIRS Water vapor Validation Experiment (AWEX) as well as two other field campaigns and has been launched in 25 soundings so far.

Important features of the CU-CFH instrument are:

- Microprocessor controlled
- Improved mirror calibration
- Optimized optical condensate detection
- Digital interface with ozone sonde
- Simplified instrument preparation and set-up

The microprocessor control allows an enhanced feedback control loop to maintain a constant frost layer, a routine to avoid condensate phase uncertainties, and other flexible control routines. The electrical requirements of this instrument are 70% below and the weight is at 1lb roughly a factor 4 less compared to the previous version of the NOAA hygrometer.

The improvement over the NOAA hygrometer, most relevant for AIRS validation, is the capability of continuous measurements from the surface to the middle stratosphere. While the NOAA hygrometer usually begins proper operation in the middle troposphere, with one additional data gap due to a sensitivity chance in the upper troposphere, the CU-CFH instrument provides accurate data from launch. An example for the excellent performance of the CFH sonde is shown in figure 2. This figure shows 1.2 second resolution data for the CFH and 2 second resolution data for the RS92.

The accuracy of frost point temperature measurements for this instrument is less than 0.5K. This translates to a 4-6% accuracy of the relative humidity value, depending on altitude. Considering the accuracy of the temperature measurement, which is estimated to be less than 0.2K, the total uncertainty in relative humidity is 6-8%. The integrated precipitable water column derived from this instrument is estimated to be better than 5%.

During AWEX this instrument was used to evaluate the performance of other radiosonde sensors, i.e. the RS80, RS90, RS92 radiosondes from Vaisala as well as the Snow White hygrometer from Meteolabor. Here only the comparison with the RS92 are shown, which also are the first RS92 soundings launched in North America. (figure 3). These comparisons show a very good agreement between these sensors with mean differences less than 3% RH throughout the entire troposphere. A small drying of the RS92 values compared to the CFH between the surface and 10 km is currently under investigation. Due to solar flare activity ARIS was not operational during most of AWEX. Nevertheless, this campaign provided an important intercomparison of the various sensors used in the AIRS validation program.

San Cristóbal soundings in coordination with AVE

Two frost point soundings using the NOAA/CMDL frost point hygrometer were launched at San Cristóbal, Galapagos in January 2004 in cooperation with the NASA WB-57 high altitude research aircraft operations out of Costa Rica. The WB-57 carried a total of four water instruments on board, a TDL water vapor hygrometer, a second TDL for isotopic composition of water vapor, a frost point hygrometer for water vapor, and a Lyman- α instrument for total water vapor.

These two soundings were timed with an AIRS overpass as well as with an overflight of the WB-57. During the second sounding, the aircraft performed a descent and an ascent over San Cristóbal at the time that the balloon was rising through the upper troposphere. Relative humidity from this sounding is shown in figure 4. The aircraft data are not yet available, but it is expected that this sounding will provide an excellent basis for intercomparison between all four aircraft hygrometers and the balloon borne frost point hygrometer. The layer of ice supersaturation between 15 and 16 km is topped by the tropopause and should give some important information about the levels of supersaturation that can be achieved in the presence and absence of particles.

3. Issues

The supply and performance of NOAA/CMDL frost point hygrometers has been insufficient during this period. The development of the improved CU-CFH instrument in cooperation with the Instrument Development Facility of Cires at the University of Colorado eliminates this bottleneck and allows launching an extended number of instruments.

The Snow White sensor was last used as part of the AWEX field campaign. It was not used in other soundings, since its inherent limitations make it less suitable for AIRS validation measurements. A larger number of CFH sondes will be flown instead.

4. Future work

Monthly soundings at Hilo, HI will resume beginning in April 2004 using the CU-CFH. These soundings will also support the validation effort of John Barnes. Some soundings will be launched to provide a calibration check for the raman lidar stationed at the Mauna Loa observatory.

One campaign at San Cristóbal, Galapagos is planned for July 2004 with 3 CU-CFH soundings. These soundings will also carry RS90 radiosondes to increase the statistics for the comparison of the RS90 humidity sensor. Monthly soundings are planned following this campaign.

Biweekly frost point/ozone soundings at Boulder, CO will be coordinated with AIRS overpasses to provide a good data source for continental validations. These soundings will be launched on a regular schedule, and cover cloudy and clear conditions as long as balloon launches are possible.

A cooperation with the University of the island La Reunion (55.48°E , 21.06°S) is in preparation and will be funded in part by the European SCOUT program. This site is a complementary site for Hilo, HI with a similar latitude in the Southern hemisphere. Some soundings will be coordinated with AIRS overpasses.

5. Figures

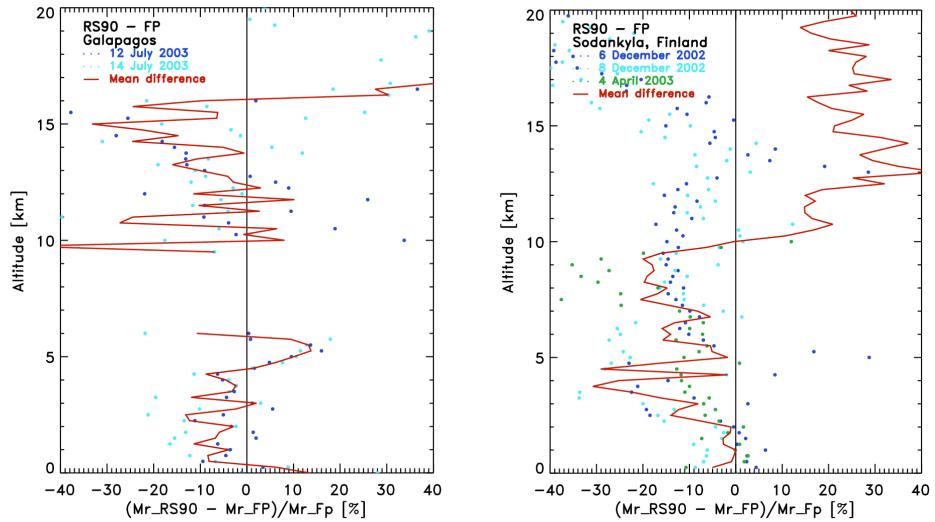


Figure 1. Relative difference between Vaisala RS90 and NOAA/CMDL frost point hygrometer water vapor mixing ratio. The tropopause at Galapagos is at 16.5 km, at Sodankylä at 9 km.

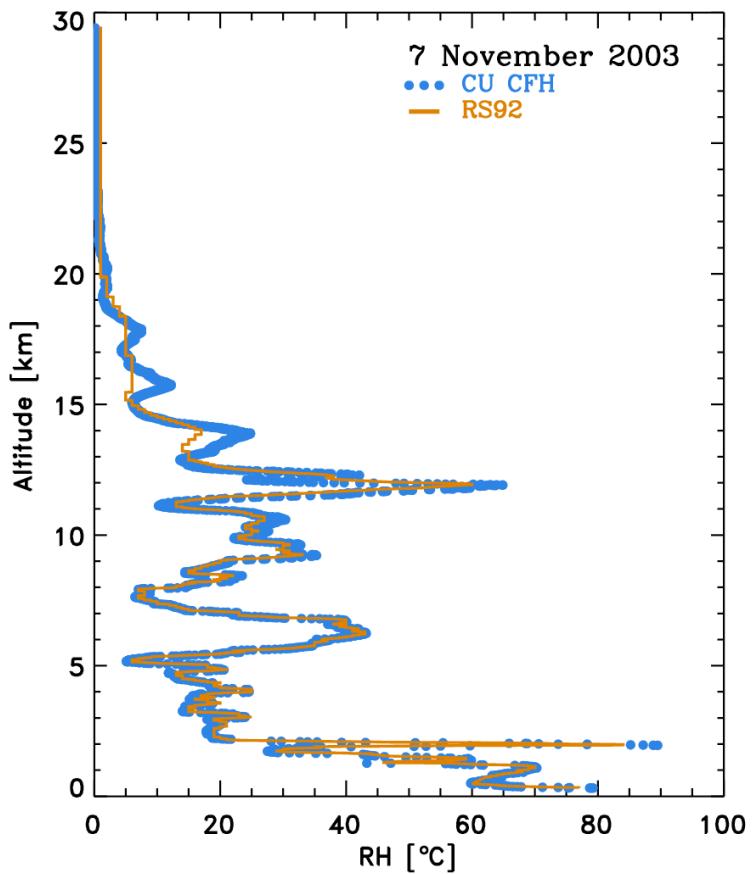


Figure 2. Sounding during AWEX using the CU-CFH, Vaisala RS80-H and Vaisala RS92. Relative humidity obtained every 1.2 second by the CU-CFH and every 2 seconds by the RS92 are shown.

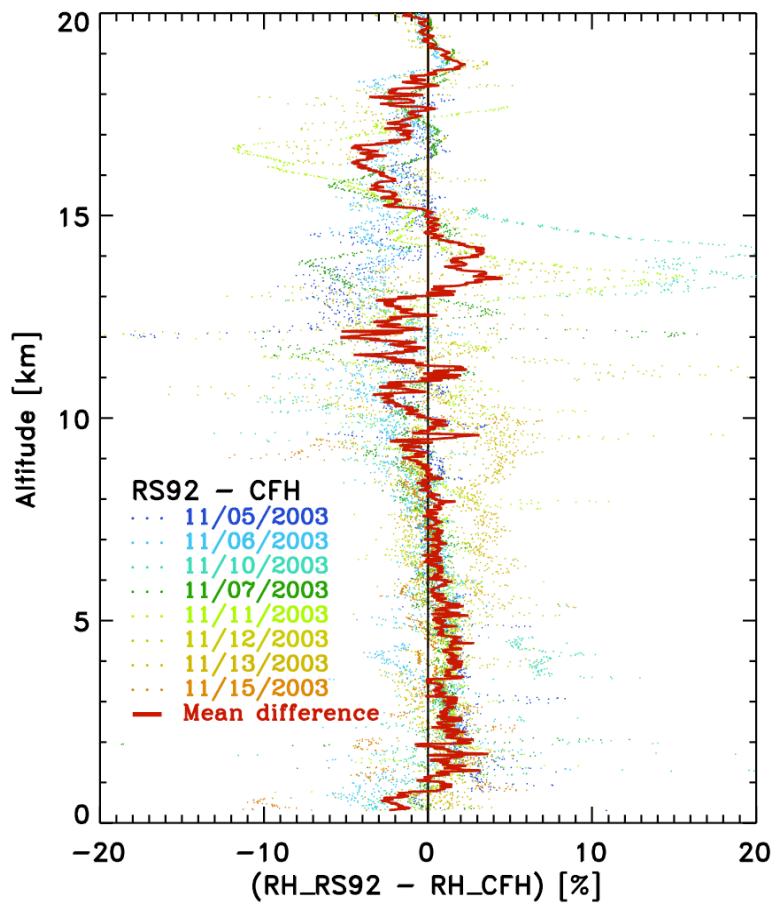


Figure 3. Mean relative humidity difference between the Vaisala RS92 radiosonde humidity sensor and the CFH relative humidity from 8 soundings during AWEX, 5 November – 15 November 2003.

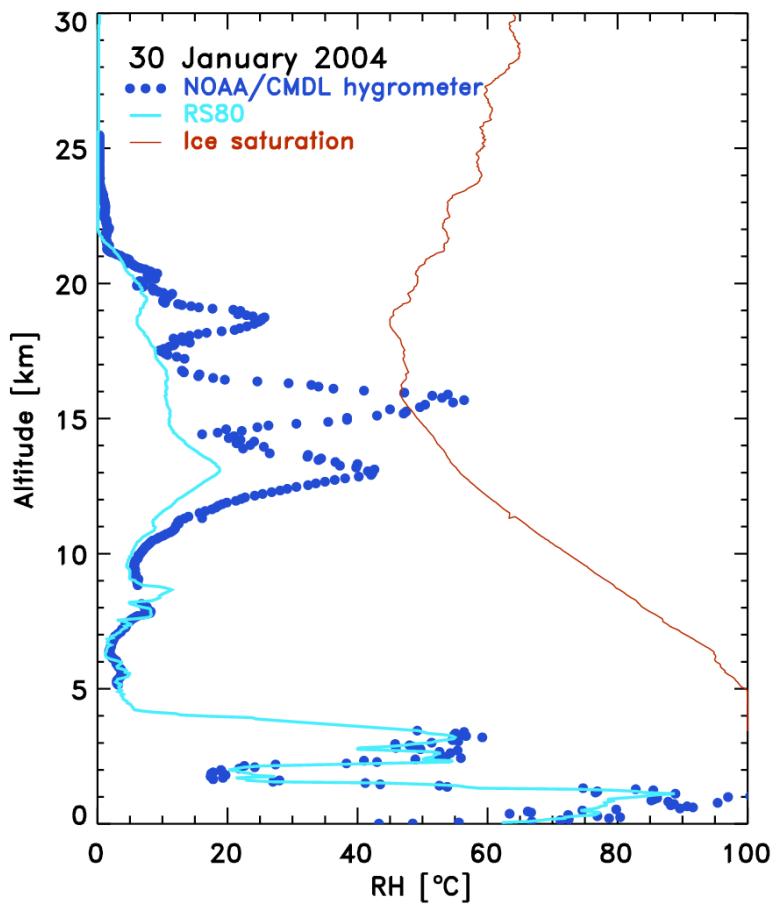


Figure 4. Relative humidity measured by the NOAA/CMDL frost point hygrometer and the Vaisala RS80-H radiosonde humidity sensor over San Cristóbal, Galapagos in coordination with the AVE WB-57 aircraft overpass.